Acoustic microscopy – a powerful tool to inspect microstructures of electronic devices (I)

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ABSTRACT (ORAL PRESENTATION)

To increase the efficiency of electronic devices their structures are getting smaller and the layered constructions are getting more complex. The inspection of these small and thin structures gives new demands on the NDT, especially in lateral and depth resolution. High-end X-ray tomography is one inspection method, which allows to detect cracks or delaminations. However, it is time consuming. Ultrasonic techniques are able to detect cracks, delaminations, and other non homogeneities, too. Acoustic microscopy is the high-end application of ultrasonic techniques. Using frequencies between 3 MHz and 2000 MHz (2 GHz) it is possible to detect defects even in the sub micron-range. In combination with scanning units with a resolution of 0.1 µm, modified transducers and special software microstructures of layered electronic devices can be inspected very fast. This method will be presented at several examples of semiconductor devices. It will be shown, that in-line-inspection with acoustic microscopy is possible.

INTRODUCTION

Since several decades ultrasonic techniques are well known. According to the increasing demands the application fields are wide spread from defect detection in large components to defect detection and characterization in the µm range resulting in a variety of different types of ultrasonic instruments modified for the different demands. Especially for inspection of small structures like in electronic devices the demands in accuracy of the scanning system, as well as in imaging characterization techniques and operation comfort are very high. The acoustic microscopes presented in this paper belongs to the type of microscope with the most efficient scanning systems as well as ultrasonic transducers covering most of the application demands.

TECHNICAL BACKGROUND

One can distinguish between acoustic microscopes at lower frequencies starting at 1 MHz to 100 MHz, a middle frequency range from 100 to 400 MHz, and acoustic microscopes in the high frequency range starting at 400 MHz to 2 GHz. Generally, the low frequency acoustic microscope allows to inspect the volume of a component whereas the high frequency acoustic microscope can be used for surface and surface near inspection of components. Beside this the type of the transducer to be used depends on the intended application. Here the frequency, bandwidth, opening angle and the radius of curvature for the focal distance are some of the points, which have to be taken into account. Today, the handling of most of the instruments is computer controlled, as well as data acquisition, analysis and documentation. Some of the acoustic microscopes are controlled by graphical user interfaces (Fig. 1) [1]. This is very comfortable for the user and even allows persons, which are not familiar with the ultrasonic technique quickly to learn controlling the instrument. Acoustic microscopy gives the advantage to inspect samples nondestructively in different “cuts”, like the B-scan, which is a cross section through the sample, or the C-scan, which gives an acoustic image of a layer of the interior of the sample. Beside these special scan types, like G- and X-scans allows to “cut” nondestructively the samples interior in layers and therefore to get an overview of the depth and location of defects inside the sample (Fig. 2). Electronic devices like flip chip, chip-on-board or chip-on-flex are samples with layered structures ideally to be inspected by acoustic microscopy (Fig. 3).

Scanning systems

Most of the instruments have x-y-scanners with scanning sizes between 60 µm and 200 mm. The z-direction is moved by hand or is motor controlled with a newly developed ultrasonic auto focus mechanism. The highest positioning accuracy with a motorized mechanic is given with 0.1 µm. Typically step motor scanners were used for standard applications.

Fig. 1: Acoustic microscope Evolution II, working in the frequency range from 1 to 400 MHz. It consists out of a high speed high resolution linear scanner system, PC-controlled workstation, and various transducers. The customer can choose the set of transducers and the scanning system individually.

420 000 data points are counted for a distance of 4mm for this high precision stepper standard. Beside the high noise level during operation these scanners are quite rough and due to the typical spindle driver mechanism the mechanical accuracy is limited for high frequency applications and high magnifications.

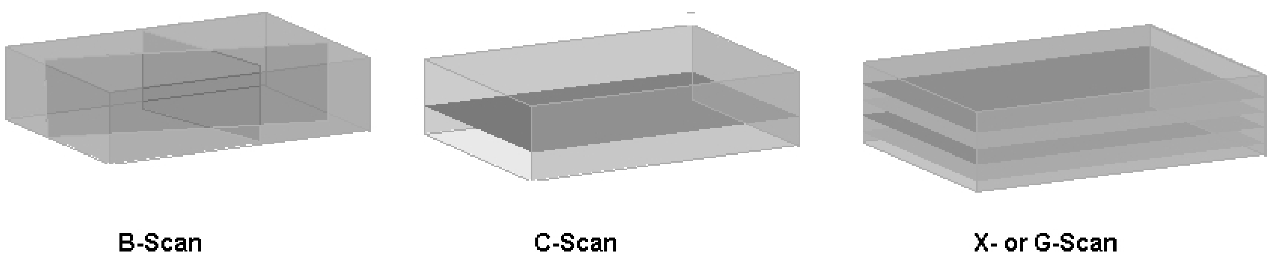

Fig. 2: Different scan types of A-, B-, and C-Scans are well known. The gate settings were done by software. Just two mouse clicks are necessary to determine the gate position and width. For X- and G-Scan the number and thickness of the single scan is given by the gate width of the B- and C-Scan gates.

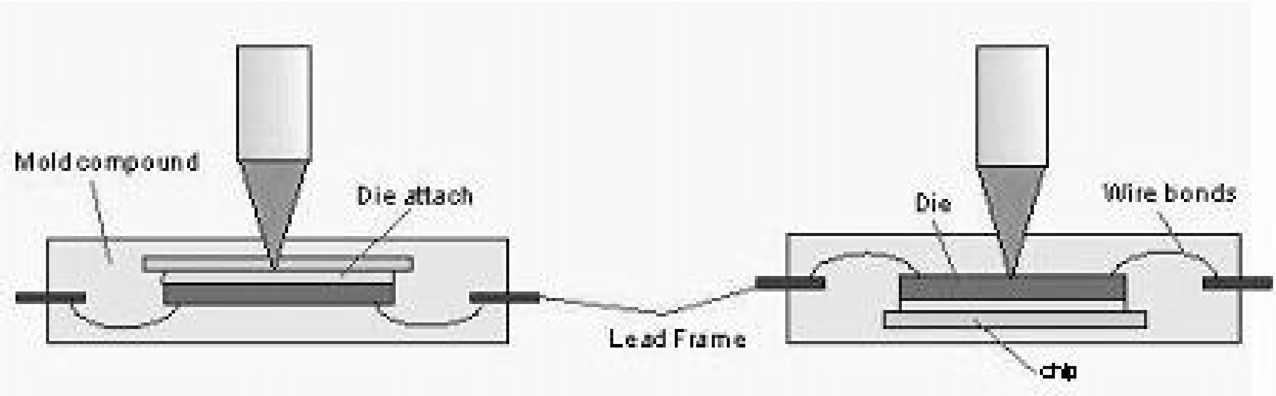

Fig. 3: Ultrasonic inspection of a flip chip is possible from both sides of the sample.

For special applications a new linear driver scanner generation is used. Especially for inspection of small defects the scanner resolution has to be smaller than the smallest defect structure to allow the imaging of the defect. A newer high speed, high resolution scanner generation is a xyz-scanner with a linear motor system giving the SAM unmatched accuracy and robustness. Here, the scanner resolution is better than 0.1 µm for x, y and z direction. The electronic positioning control unit is for all scan areas 4 times better in its internal accuracy for such precise and mechanically stable inertial balanced scanner. This unique scanner has a top speed of 1m/sec and 10 m/sec^2 acceleration. Hence high resolution acoustic micrographs can actually chosen from a spectrum running from 128 x 128 pixel up to 32000 x 32000 pixel per image to see acoustic details that were not viewable before. Special developed transducers with a center frequency of 200, 300, 400 MHz or higher can be used for best image resolution in combination with this scanner system only. Suppose you are analyzing a flip chip failure .The solder bump bonds often hold important adhesive data for the analysis. The very high resolution image with a high pixel number itself will look extremely sharp even if the blow up function is used to enlarge for example just one bump bond with true magnification, not just bigger pixels. Tiny voids and micro cracks can be detected.

Instrument settings
Beside the well known A-, B-, and C-Scan the EVOLUTION II offer as well other scan types thus as the X-Scan and G-Scan. Here, the sample interior is “cut” in layers during the scan. The signals are determined depending on the time gate settings. For the G-Scan the gate settings can be chosen individually including automated gain adjustment due to higher sound wave damping inside a specimen. Due to the software the number of scans for the X-Scan is defined by the width of the B-Scan gate divided by the width of the C-Scan gate. The gate settings for the different scan types can be chosen just by software control with one click.

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